Allowable Isotopic Mass Limits for the Type 4 Contents in the Model 9977-96 SGQ-EC1 Unshielded Engineered Container

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Introduction

This report presents the calculated allowable radioactive material mass limits for "Type 4" contents in the Model 9977-96 transportation package when using the unshielded SGQ-EC1 container. The allowable mass limits were based on the isotopic mass that resulted in a dose rate on the external surface of the packaging of 190 mrem/hr.

Background

Lawrence Livermore National Laboratory's (LLNL) Radioactive Materials Packaging and Transportation Staff (P&T Staff) reviewed the *Safety Analysis Report for Packaging (SARP) for the Model 9977-96, Addendum 3, Revision 4 for the Type 4 Contents*, which was prepared for the Department of Energy by Savannah River National Laboratory (SRNL).[1] The results of the LLNL review are documented in a Technical Review Report (TRR).[2]

Type 4 contents in the Model 9977-96 may include ^{238}Pu, ^{239}Pu, ^{241}Am, ^{244}Cm, ^{252}Cf, ^{90}Sr, ^{226}Ra, ^{137}Cs, ^{60}Co and ^{192}Ir, with the Special Actinide Isotopes (^{242m}Am, ^{243}Cm, ^{245}Cm, ^{247}Cm, ^{249}Cf and ^{251}Cf) limited to a total of 1000 ppm. The Type 4 contents pertain primarily to the Off-Site Source Recovery Project (OSRP).

Prior to the approval by EM-45 of the Type 4 contents, the Model 9977-96 Package was certified under two Certificate of Compliance Numbers, i.e., USA/9977/B(M)F-96 (DOE)[3] and USA/9977/B(M)F-96 (DOE-S/T-1),[4] covering transportation and periodic and extended maintenance, respectively. For transportation, the Safety Analysis Report for Packaging is S-SARP-G-0001, Revision 2 (August 2007).[5] Extended maintenance for a limited number of 9977-96 packagings are covered by Addendum 1, *Justification for DNDO Contents*, S-SARA-G-00003, Revision 2 (October 2008).[6]

Three different types of shielded containers were proposed in the SARP for use in transporting the Type 4 contents. The first, for shielding gamma sources, is constructed of lead, encapsulated in stainless steel, with a threaded stainless steel closure, and is identified as SGQ-SC1. The second, for shielding of neutron sources, is constructed of high density polyethylene (HDPE), and is identified as SGQ-SC2. The third, also for gamma shielding, is constructed of tungsten, and is also encapsulated in stainless steel, with a threaded stainless steel closure, and is identified as SGQ-SC3. A fourth engineered container, which is unshielded, was also proposed for use in the Model 9977-96 for the Type 4 contents, and was identified as SGQ-EC1.

The SARP submittal contained calculated allowable mass limits for each of the proposed isotopes in the Type 4 contents for the shielded containers [i.e., the SGQ-SC1 (for gamma sources) and SGQ-SC2 (for neutron sources)]. From the calculations, the side surface dose rate emerged as the limiting set that governed the value of the shippable mass for each isotope, placed in the appropriate shielded container that constituted the Type 4 contents. The mass limits were based on a surface dose rate of 190 mrem/hr, which provided a 5% margin to the regulatory limit of 200 mrem/hr under normal conditions of transport (NCT) for a nonexclusive use shipment. The mass limit results for the SGQ-SC1 container were bounded for the use of the SGQ-SC3 container, since the tungsten container provides more gamma attenuation than the lead container. LLNL P&T Staff reviewed these derivations of allowable mass limits, performed confirmatory analysis, and through discussions with SRNL personnel, arrived at an agreeable set of conservative mass limits for use of the SGQ-SC1, SGQ-SC2, and SGQ-SC3 shielded

containers. These mass limits for each isotope, which are explicitly identified in the Certificate of Compliance (CoC) for the Model 9977-96, are listed below in Table 1.

Table 1.
Maximum Allowable Isotopic Mass Limits for Use of the SGQ-SC1, SGQ-SC2, SGQ-SC3 Shielded Containers in the Model 9977-96 Radioactive Material Transportation Package

Isotope	Maximum Mass Limit [g]	Appropriate Shielded Container(s)
Gamma Emitters		
Co-60	1.0E-04	SGQ-SC1 or SGQ-3
Cs-137	1.0E-01	SGQ-SC1 or SGQ-3
Ir-192	3.8E-03	SGQ-SC1 or SGQ-3
Sr-90/Y-90	1.0E+00	SGQ-SC1 or SGQ-3
Ra-226	2.0E-01	SGQ-SC1 or SGQ-3
Neutron Emitters*		
Am-241 w/ Be	1.0E+00	SGQ-SC2
Cf-252	6.7E-06	SGQ-SC2
Cm-244	1.0E+00	SGQ-SC2
Pu-238 w/ Be	2.0E-01	SGQ-SC2
Pu-239 w/ Be	6.6E+01	SGQ-SC2

*Gamma contribution to dose rate was accounted for in establishing mass limits

For the use of the unshielded SGQ-EC1 container, however, the SARP submittal did not contain any allowable isotopic mass limits or any shielding calculations. The administrative approach proposed in the SARP submittal, and approved in the CoC, for using the SGQ-EC1 for the isotopes identified as Type 4 contents is solely contingent upon the source(s) satisfying the administrative dose rate limits of 180 mrem/hr (on contact) and 9 mrem/hr (at a distance of 1 meter) by measurement.

Approach

The following is an outline of the approach used to calculate the allowable radioactive material mass limits for "Type 4" contents in the Model 9977-96 transportation package when using the unshielded SGQ-EC1 container. The gamma and neutron source spectra from the neutron emitters were obtained using the computer code RASTA.[7] The sources from the pure gamma emitters were obtained using ORIGEN-ARP.[8] For the isotopes with beryllium impurity, the neutron source from the (α, n) reaction was obtained using the limiting case with 90 w% beryllium and 10 w% actinide. These source terms are listed in Table 2. Using these source terms and the calculational model shown in Figure 1, the dose rate on the external surface of the package was calculated using the Monte Carlo radiation transport computer code MCNP.[9] The sources were treated as point sources in the simulation though it is shown as a sphere of finite volume in Figure 1 for the purposes of clarity. The limiting dose rate occurred on the external side surface of the package. Similar to the approach used for the SGQ-SC1 and SGQ-SC2 containers, the limiting mass of each isotope that could be placed in the unshielded SGQ-EC1 container was obtained for an external surface dose rate of 190 mrem/hr. This constitutes a 5% margin from the regulatory limit of 200 mrem/hr on the package surface under Normal Conditions of Transport (NCT) for a non-exclusive use shipment.

Table 2.
Source Terms for Isotopes (i.e., Isotopes in 9977-96 Radioactive Material Transportation Package, Addendum 3, Revision 4 for the Type 4 Contents)

	Rates per 1 g Source		Ratio
Isotope	**Neutrons/Second**	**Gammas/Second**	**Gamma/Neutron**
Co-60		8.56E+13	
Cs-137		3.25E+12	
Ir-192		8.12E+14	
Sr-90/Y-90		1.78E+12	
Ra-226		1.25E+11	
Am-241	9.58E+06	1.47E+11	1.53E+04
Cf-252	2.31E+12	9.61E+12	4.16+00
Cm-244	2.87E+08	3.18E+11	1.11E+03
Pu-238	4.80E+07	7.16E+10	1.49E+03
Pu-239	1.38E+05	9.80E+07	7.10E+02

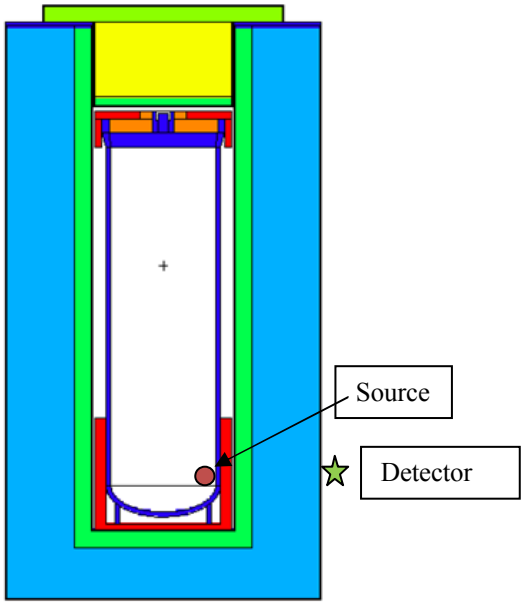

Figure 1. MCNP Input Model used in the Shielding Calculations

Results and Conclusions

The LLNL P&T staff has concluded that the operators of the Model 9977-96 package using the SGQ-EC1 container for Type 4 contents would benefit from having identified maximum allowable mass limits that are based on quantitative determinations. The LLNL P&T Staff have performed shielding calculations to establish maximum allowable isotopic mass limits for use of the unshielded SGQ-EC1 container in the Model 9977-96 package with the Type 4 contents when a conservative external dose rate of 190 mrem/hr is assumed (see Table 3).

As can be seen in Table 3, the allowable mass of the gamma-emitting isotopes in the SGQ-EC1 unshielded container are at least 25-times less (i.e.,3.92%) than that allowed in the SGQ-SC1 lead-shielded container. For gamma emitting isotopes with relatively soft spectra the allowed masses for the SGQ-EC1 are less than 1% of the shielded mass limits with the SGQ-SC1. For the neutron emitters the allowable mass limits when placed in the SGQ-EC1 drop by factors ranging

from 2.5–3.7 (~40%–26%) when compared to the shielded mass limits with SGQ-SC2. These comparisons show that the neutron shielding provided by SGQ-SC2 is not nearly as effective as the gamma shielding provided by SGQ-SC1.

Table 3.
Maximum Allowable Isotopic Mass Limits for Use of the SGQ-EC1
Unshielded Container in the Model 9977-96 Radioactive Material Transportation Package

Isotope	Maximum Mass Limit in SGQ-EC1 Container [g]	Percentage of Mass Limit in SGQ-EC1 as Compared to that Allowed in the Appropriate Shielded Container
Gamma Emitters		
Co-60	3.92E-06	3.9%
Cs-137	1.97E-04	0.2%
Ir-192	1.39E-06	0.04%
Sr-90/Y-90	4.15E-03	0.4%
Ra-226	6.15E-03	3.1%
Neutron Emitters*		
Am-241 w/ Be	3.71E-01	37.1%
Cf-252	1.77E-06	26.4%
Cm-244	3.76E-01	37.6%
Pu-238 w/ Be	7.47E-02	37.3%
Pu-239 w/ Be	2.60E+01	39. 4%

*Gamma contribution to dose rate was accounted for in establishing mass limits

The approaches used to derive the results presented in this report, in terms of developing the source terms, the shielding model, and the calculations, are consistent with the guidance provided in Regulatory Guide 7.9, *Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material,*[10] and in the *Packaging Review Guide for Reviewing Safety Analysis Reports for Packaging.*[11]

References

[1] *Model 9977, Safety Analysis Report For Packaging, Addendum 3, Justification for Small Gram Quantity Contents*, S-SARA-G-00006, Revision 4, Savannah River Packaging Technology, Savannah River National Laboratory, Aiken, South Carolina, March 2010.

[2] Technical Review Report for the *Justification for Small gram Quantity Contents Safety Analysis Report for Packaging Model 9977-96*, Addendum 3, S-SARA-G-00006, Revision 4, March 2010, Lawrence Livermore National Laboratory, LLNL-TR-438431, April 23, 2010.

[3] USA/9977/B(M)F-96 (DOE), *United States Department of Energy Certificate of Compliance for Radioactive Materials Packages, Model 9977*, Revision 4, United States Department of Energy, Washington, DC, expires October 31, 2012.

[4] USA/9977/B(M)F-96 (DOE-S/T-1), *United States Department of Energy Certificate of Compliance for Radioactive Materials Packages, Model 9977*, Revision 0, United States Department of Energy, Washington, DC, expires December 31, 2013.

[5] *Safety Analysis Report for Packaging, Model 9977, B(M)F-96*, S-SARP-G-00001, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Washington Savannah River Company, Savannah River Site, Aiken, SC (August 2007).

[6] *Safety Analysis Report for Packaging, Model 9977, Addendum, Justification for DNDO Contents*, S-SARA-G-00003, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC (October 2008).

[7] Nathan, S. J., Ed., *Radiation Source Term Analysis Code RASTA User Guide (U)*, WSMS-CRT-97-0013, Revision 4, Washington Safety Management Solutions, Aiken, SC, February 2004.

[8] ORIGEN-ARP, Versions 5.0/5.1.01, *Isotope Generation and Depletion Code*, CCC 725/732, Radiation Safety Information Computational Center, May 2004/March 2007.

[9] X5-Monte Carlo Team, *MCNP-A General Monte Carlo N-Particle Transport Code*, Version 5.1.40, Los Alamos National Laboratory, February 2006.

[10] Regulatory Guide, Office of Nuclear Regulatory Research, Regulatory Guide 7.9, *Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material*, Nuclear Regulatory Commission, Revision 2, March 2005.

[11] DiSabatino, et.al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packaging,* Lawrence Livermore National Laboratory, UCID-21218 Rev. 3, February 2008.